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Operation

JANGLE

NEVADA PROVING GROUNDS
OCTOBER-NOVEMBER 1951

Project 2.3-2

FOXHOLE SHIELDING OF GAMMA RADIATION

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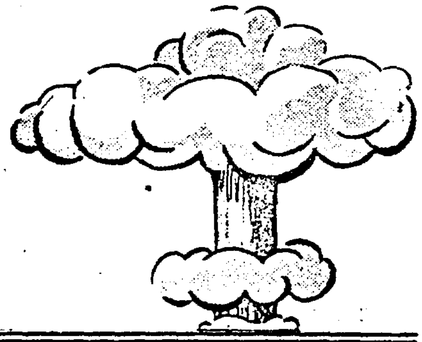

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21 Report on OPERATION JANGLE,

PROJECT 2.3-2.

6 FOXHOLE SHIELDING OF GAMMA RADIATION,

by

10 THOMAS G. WALSH.

11 27 June 1952,

12 21p.

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PROJECT 2.3-2

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ABSTRACT

This project was designed by the Corps of Engineers to evaluate the protection afforded by foxholes against the gamma radiation emitted by atomic weapons detonated on the surface and beneath the ground. Film dosimeters were used to measure total gamma ray doses at different depths in one and two-man foxholes as well as in soil pipes sunk into the ground. The film dosimeters were contained in National Bureau of Standards' type holders and responded to gamma radiation of energy greater than 120 Kev. In the report, all doses are given in terms of roentgens and a reading of 650r (roentgens) is taken as the lethal dose; that is, the dose which will cause death to nearly 100 % ~~per cent~~ of exposed personnel.

The major conclusions of this experiment, based on the data obtained in the above manner, follow:

1. Standard foxholes, as described in FM 5-15, provide excellent protection to personnel from the gamma radiation emitted during the detonation of an atomic weapon on the surface of the ground. The results show that the doses in the bottom of such foxholes located in the crosswind direction during Operation JANGLE were less than 10 per cent of the surface doses at identical locations. Since the foxholes were located outside of the major fall-out pattern, the complete dose measured was due to scattered prompt radiation. If the foxholes had been located downwind, however, the doses would have been higher, since fall-out into the foxhole and scattered radiation from the contamination on the surface would contribute more significantly to the total dose. There are indications that these contributions will not materially change the per cent of surface-received radiation reaching trained personnel in the bottom of the foxholes. An increase of surface contamination will increase the surface dose as well as the dose at the bottom of the foxhole, thereby maintaining the ratio between the two. The contaminated matter that falls into the foxhole can easily be removed by occupying personnel before it has time to increase the doses received to any great extent.

2. Except in those areas covered by extensive fall-out, foxholes also provided effective shielding in the case of the underground detonation of Operation JANGLE. The doses at the bottom of the foxholes varied from about 24 to 38 per cent of the surface doses at distances greater than 2500 feet from the burst. A great portion of this

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dose, about 90 per cent, was obviously due to radioactive matter that fell into the foxhole, because the doses measured in the holes during the surface shot were approximately 10 per cent of those measured during the underground shot of identical yield. It is expected that both bursts contributed equally to the doses as far as prompt radiation is concerned.

3. The doses obtained from the detonation of atomic weapons on the surface or underground receive contributions from prompt gamma radiation, radiation emanating from column and cloud, and from residual activity due to fall-out of radioactive matter. No base surge activity was evident.

4. The complete doses at the bottom of the foxholes after the surface burst of this operation were attributable to scattered prompt radiation in addition to a small contribution from the column and cloud; no material contribution from fall-out or residual activity was evident. This lack of effect undoubtedly resulted from the location of the foxholes in the crosswind direction. If the foxholes had been located downwind, there would have been a material contribution from fall-out and residual activity. It is not expected that this would falsify the conclusions drawn in this report on the effectiveness of foxholes as protection for personnel against gamma radiation. (See conclusion 1, above.)

5. The major portion of the total dose measured at the bottom of the foxholes after the underground burst apparently came from fall-out matter in the foxhole. Contamination on the surface of the ground surrounding the foxhole contributed only about 10 per cent to the doses at the bottom of these structures, and prompt radiation could not contribute more than evidenced in the surface burst since both weapons were the same size. Yet, in all cases the doses were considerably higher during the underground detonation, leading to the obvious conclusion that matter falling into the foxholes played the most important role. Also, the doses in the two and one-man foxholes were equal, although the two man foxhole had twice the opening area. If the column or cloud activity contributed greatly to these doses, it could be expected that the doses in the two-man foxhole would be about twice as great as those in the one-man structure.

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVE

The main objective of this project was to determine the protection that foxholes provided from the gamma radiation emitted by surface or underground bursts of atomic weapons. Total gamma radiation intensities at different levels in foxholes were measured by means of film detectors, and the results were analyzed to determine the contributions to the total doses from prompt gamma radiation, from the residual activity due to fall-out, and from column and cloud activities.

1.2 HISTORICAL

Operation JANGLE was the first test in which atomic weapons were detonated on the surface of the ground and underground. No experimental data, therefore, existed prior to this operation concerning the intensity of gamma radiation that would result from such detonations, how this intensity would vary with distance, and the shielding from radiation afforded by foxholes. Since the results obtained by Cerar in an unnumbered project performed during Operation RANGER and the author during Operation BUSTER proved that foxholes provided excellent protection from the radiation emitted during an air burst atomic weapon, the Office of the Chief of Engineers suggested that measurements also be made during the surface and underground bursts of Operation JANGLE allowing a complete picture of the effectiveness of foxholes as shields against radiation to be determined. The project was assigned to the Special Projects Branch of the Engineer Research and Development Laboratories and was carried out as Project 2.3-2 of Operation JANGLE.

The gamma measurements were accomplished by means of National Bureau of Standards' type film dosimeters. The calibration, distribution, collection and development of the film dosimeters were performed by the personnel of Project 2.3-1, Operation JANGLE, and a complete description of the film detectors is found in that report.

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CHAPTER 2

EXPERIMENTAL PROCEDURE

2.1 FOXHOLES

Standard two-man foxholes were constructed at the Nevada Test Site at 500 foot intervals from 2000 to 5000 feet from the points of detonation of the underground and surface shots. The foxholes were placed so that their longitudinal axes lay along a line which extended 45° East of North from the location of the weapon. (See Fig. 2.1.) Each foxhole was instrumented in eleven different positions with gamma film detectors. (See Fig. 2.2.)

In addition, there were one-man foxholes constructed adjacent to those two-man foxholes located 3000 and 4000 feet from the target in such a manner that their longitudinal axes were perpendicular to the northeast line. At these latter distances a soil pipe 48 inches long and 6 inches in diameter was also sunk flush with and perpendicular to the surface of the earth. The soil pipes were instrumented along the central vertical axes at depths of 16, 32, and 48 inches with gamma detectors. The one-man foxholes were instrumented as shown in Fig. 2.3.

2.2 FILM DETECTORS

Briefly, the films were arranged in National Bureau of Standards' type holders to cover the sensitivity ranges given in Table 2.1. The film holder consisted of a bakelite container which held two dental size film packets, and was covered with a layer of 1.07 mm of tin and a layer of lead 0.3 mm in thickness. The lead suppresses gamma rays of low energy, less than 0.1 Mev, and tends to make the film response independent of the energy of the incident radiation. The tin, placed between the lead and bakelite, filters the fluorescent radiation from the lead, while the bakelite serves as an "air equivalent" layer to produce electron equilibrium near the surface of the film. A lead strip was also placed around the edges of the badge to stop tangential radiation and the whole unit then sealed with paper masking tape.

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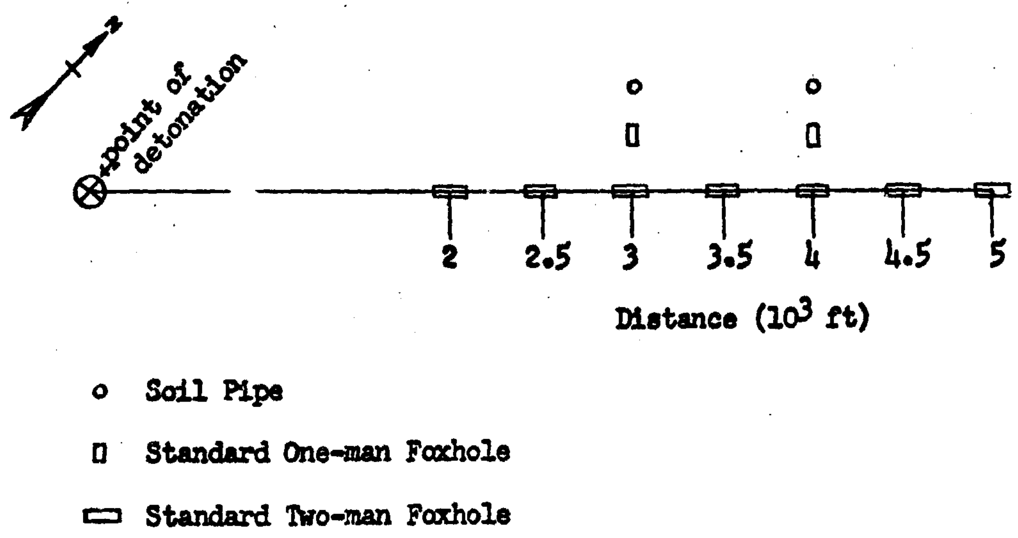

Fig. 2.1 Location of Foxholes

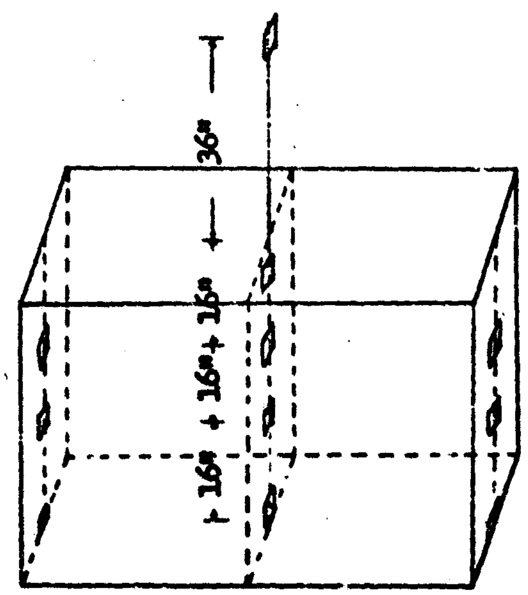

Fig. 2.2 Film Locations in Two-man Foxholes

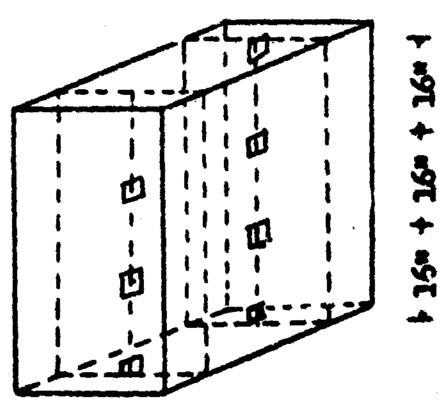

Fig. 2.3 Film Locations in One-man Foxholes

2.3 FILM PROCESSING

The films were calibrated according to standard procedures by Evans Signal Laboratory personnel prior to the shots. The exposed films were collected 50 hours after each detonation, developed, and the density of each determined. The exposures were interpreted from density versus dosage curves by comparison of the densities with those of films calibrated with a Co^{60} source.

TABLE 2.1

Types of Film Used

Emulsion Type	Packet Type	Sensitivity Range
Dupont 502		0.5r to 10r
Dupont 510	552	3r to 50r
Dupont 510, 605	554	20r to 500r
Dupont "Adlux" 556	556	[illegible]r to 1,000r
Eastman 548-0 (double coat)	548	1,000r to 10,000r

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CHAPTER 3

TEST RESULTS

3.1 GAMMA RADIATION RESULTS

The integrated gamma doses in roentgens measured in foxholes at various distances from the detonations are shown in Tables 3.1 and 3.2 for the surface and underground bursts respectively. These doses are given for five different levels in a two-man foxhole, 3 feet above the surface of the ground, at the surface, and 16, 32, and 48 inches below the surface. At each level below the surface, three doses are given in the two-man foxholes and two doses in the one-man foxhole, representing the results of films located in the positions shown in Fig. 2.2.

Figs. 3.1 through 3.6 are reproductions of the results obtained in Project 2.1A, Operation JANGLE. They depict the dose rates at one hour after the bursts, the total dose received in the first ten minutes and in one hour for both the surface and underground shots. The presentation of these graphs is necessary in this report since the film badges were not collected until fifty hours after the bursts and the graphs give an estimate of the contribution that residual radiation made to the total doses. On these graphs the locations of the foxholes have been superimposed to facilitate the evaluation of the results. Fig. 3.7 shows the prompt radiation expected from detonations of weapons of the size employed in the tests. The curves show the logarithm of the dose received as a function of the distance from the point of detonation to the films. Fig. 3.8 shows the theoretical value of the integrated dose at any time after the burst assuming a dose rate of 1 r per hour at 1 hour after the detonation and a decay law of $t^{-1.2}$. Total doses for any other dose rate may be obtained by multiplying the values on the graph by the desired rate at H+1 hours.

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TABLE 3.1

Distribution of Gamma Radiation in Foxholes (Surface Burst)

Range (ft)	Location	Two-man Foxhole			One-man Foxhole		Soil Pipe
2000	36" Above Surface		800 r				
	Surface		700				
	16" Below Surface	230	205	415			
	32" Below Surface	24	58	136			
	48" Below Surface	12.8	22	62			
2500	36" Above Surface		230 r				
	Surface		220				
	16" Below Surface	35	60	85			
	32" Below Surface	7	15	26			
	48" Below Surface	4	8.5	13.3			
3000	36" Above Surface		110 r				73 r
	Surface		90			55	
	16" Below Surface	23	36	55	6.8	6.6	10
	32" Below Surface	7.6	12.4	19.4	2.5	2.4	0.5
	48" Below Surface	2.5	4.8	6.7	1.6	1	0
3500	36" Above Surface		41 r				
	Surface		—				
	16" Below Surface	3	—	9.7			
	32" Below Surface	1.6	2.8	3.4			
	48" Below Surface	.54	.99	1.9			
4000	36" Above Surface		17 r				17 r
	Surface		9.6			—	
	16" Below Surface	1.6	3	5.6	—	0.35	—
	32" Below Surface	0.6	1.12	1.62	—	—	0.17
	48" Below Surface	—	0.54	0.57	0.39	—	—
4500	36" Above Surface		9.8 r				
	Surface		4.6				
	16" Below Surface	1	1.8	3.5			
	32" Below Surface	0.5	0.7	1.04			
	48" Below Surface	0.21	0.4	0.57			
5000	36" Above Surface		4.8 r				
	Surface		2.7				
	16" Below Surface	0.6	0.99	2.95			
	32" Below Surface	0.3	0.5	0.75			
	48" Below Surface	0.17	0.2	0.38			

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TABLE 3.2

Distribution of Gamma Radiation in Foxholes (Underground Burst)

Range (ft)	Location	Two-man Foxhole			One-man Foxhole		Soil Pipe
2000	36" Above Surface		3850 r				
	Surface		2300				
	16" Below Surface	1150	--	800			
	32" Below Surface	700	1000	555			
	48" Below Surface	200	200	200			
2500	36" Above Surface		1000 -- 550 r				
	Surface		78				
	16" Below Surface	78	98	115			
	32" Below Surface	43	56	50			
	48" Below Surface	73.4	94	96			
3000	36" Above Surface		175 r				155 r
	Surface		103			75	
	16" Below Surface	30	42	37	20	--	7
	32" Below Surface	22	23	20	15	11	3
	48" Below Surface	43.5	45	54	41	38	3
3500	36" Above Surface		--				
	Surface		48				
	16" Below Surface	12	17	15			
	32" Below Surface	9	10	9			
	48" Below Surface	15	15	22			
4000	36" Above Surface		32 r				28 r
	Surface		22			14	
	16" Below Surface	6	7	15	7	4	2
	32" Below Surface	5	3.4	7.2	3.7	2.8	0
	48" Below Surface	6	8.4	8.6	5	9.8	1.1
4500	36" Above Surface		22 r				
	Surface		10				
	16" Below Surface	4	5	5			
	32" Below Surface	5.8	2.8	2.8			
	48" Below Surface	--	7.7	8.9			
5000	36" Above Surface		73 r				
	Surface		23				
	16" Below Surface	15	15	67			
	32" Below Surface	21.5	22.6	15			
	48" Below Surface	--	21	19			

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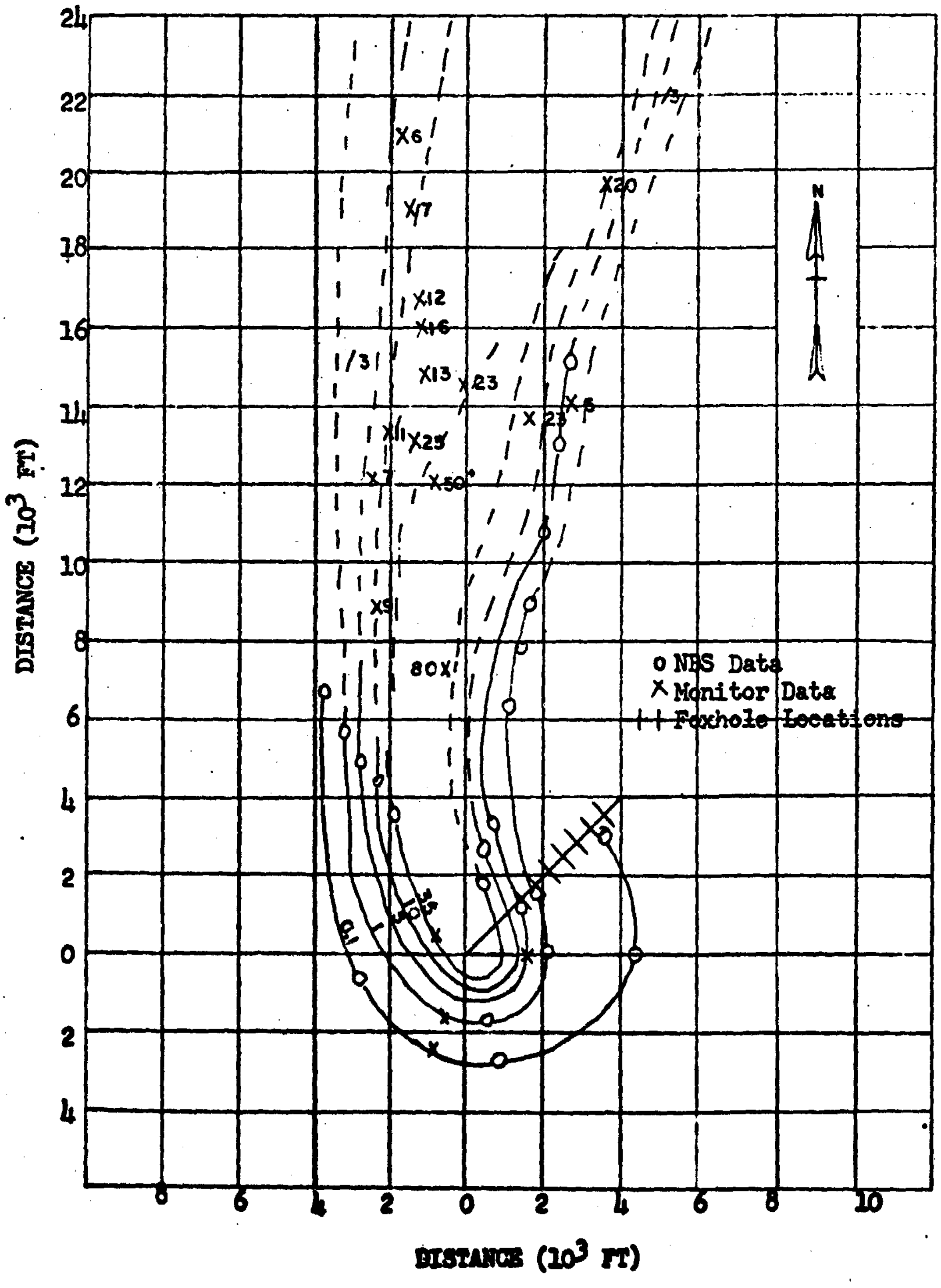

Fig. 3.1 Surface Burst, Iso-Rate Contours At 1 Hr.

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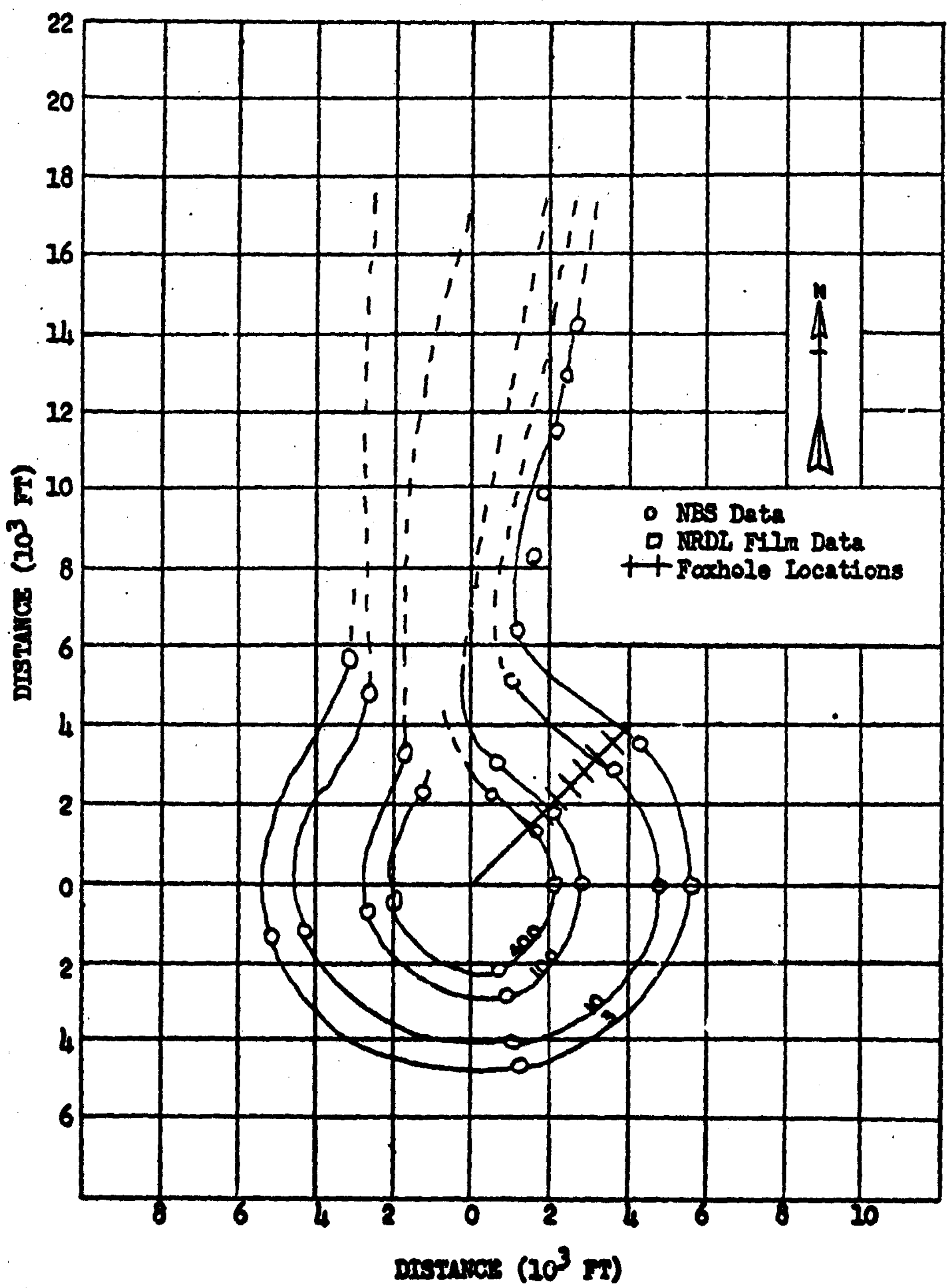

Fig. 3.2 Surface Burst, Iso-Dose Contours at 10 Minutes

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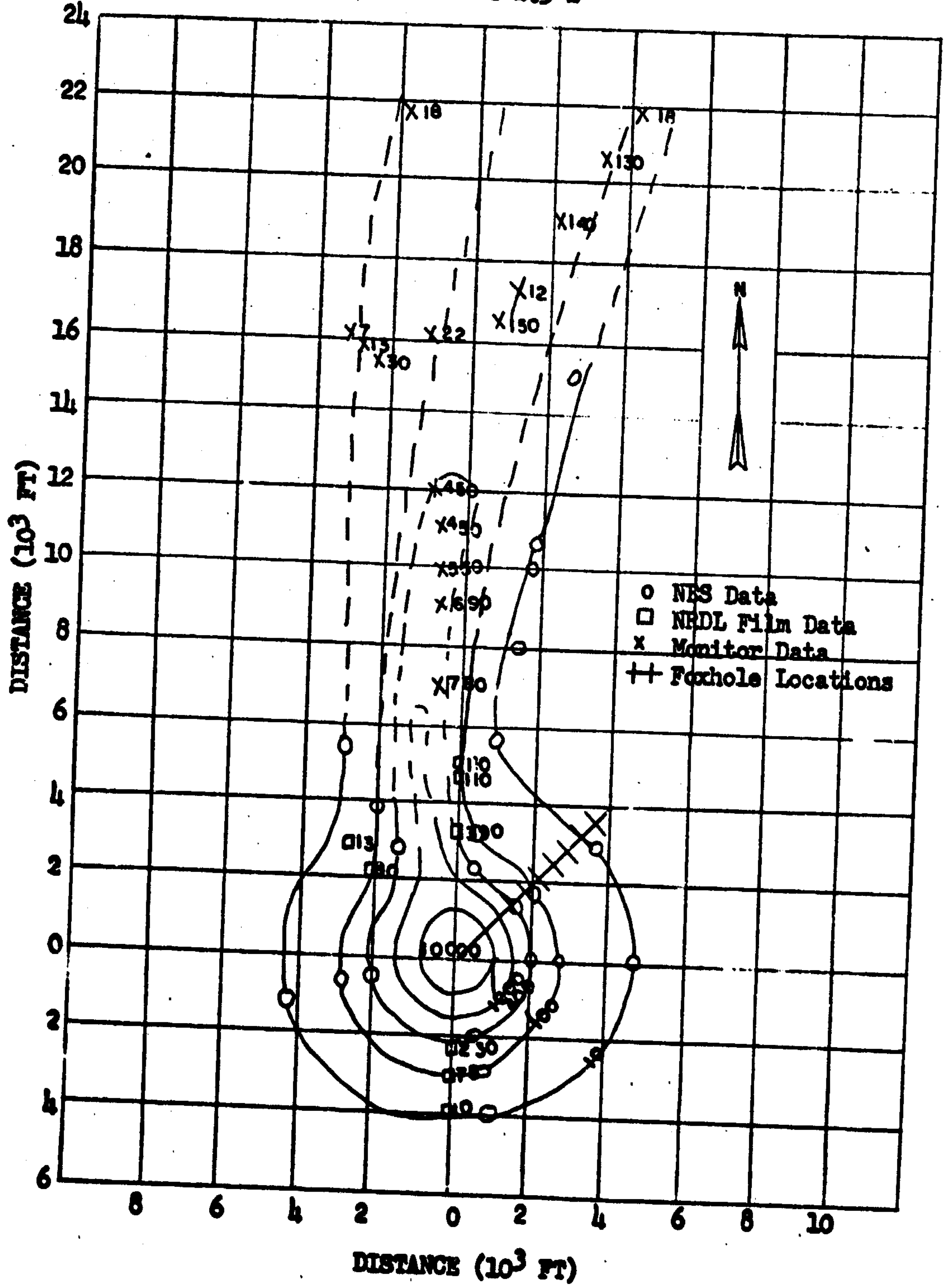

Fig. 3.3 Surface Burst, Iso-Dose Contours At 1 Hour

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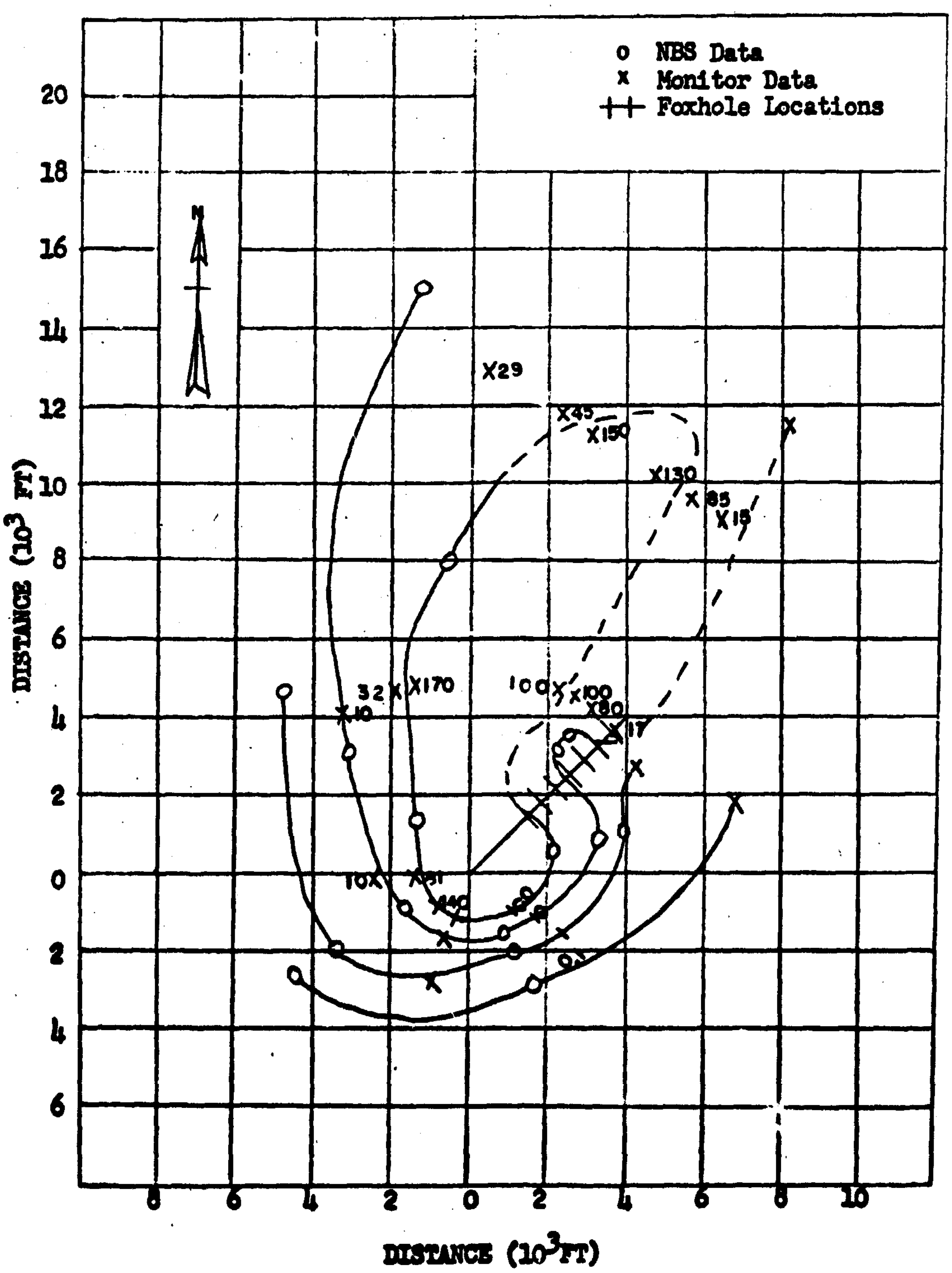

Fig. 3.4 Underground Burst, Iso-Rate Contours at 1 Hour

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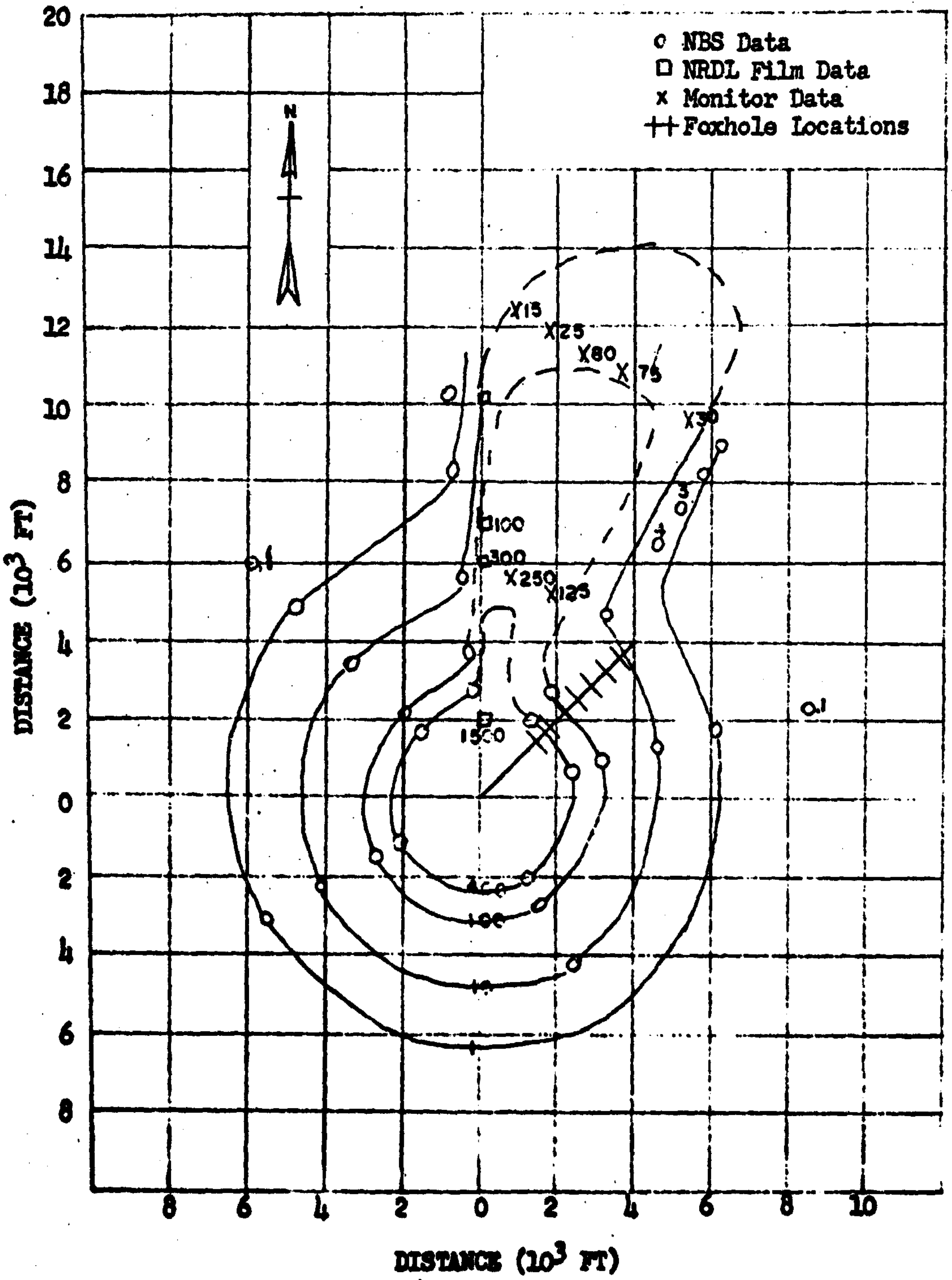

Fig. 3.5 Underground Burst, Iso-Dose Contours At 10 Minutes

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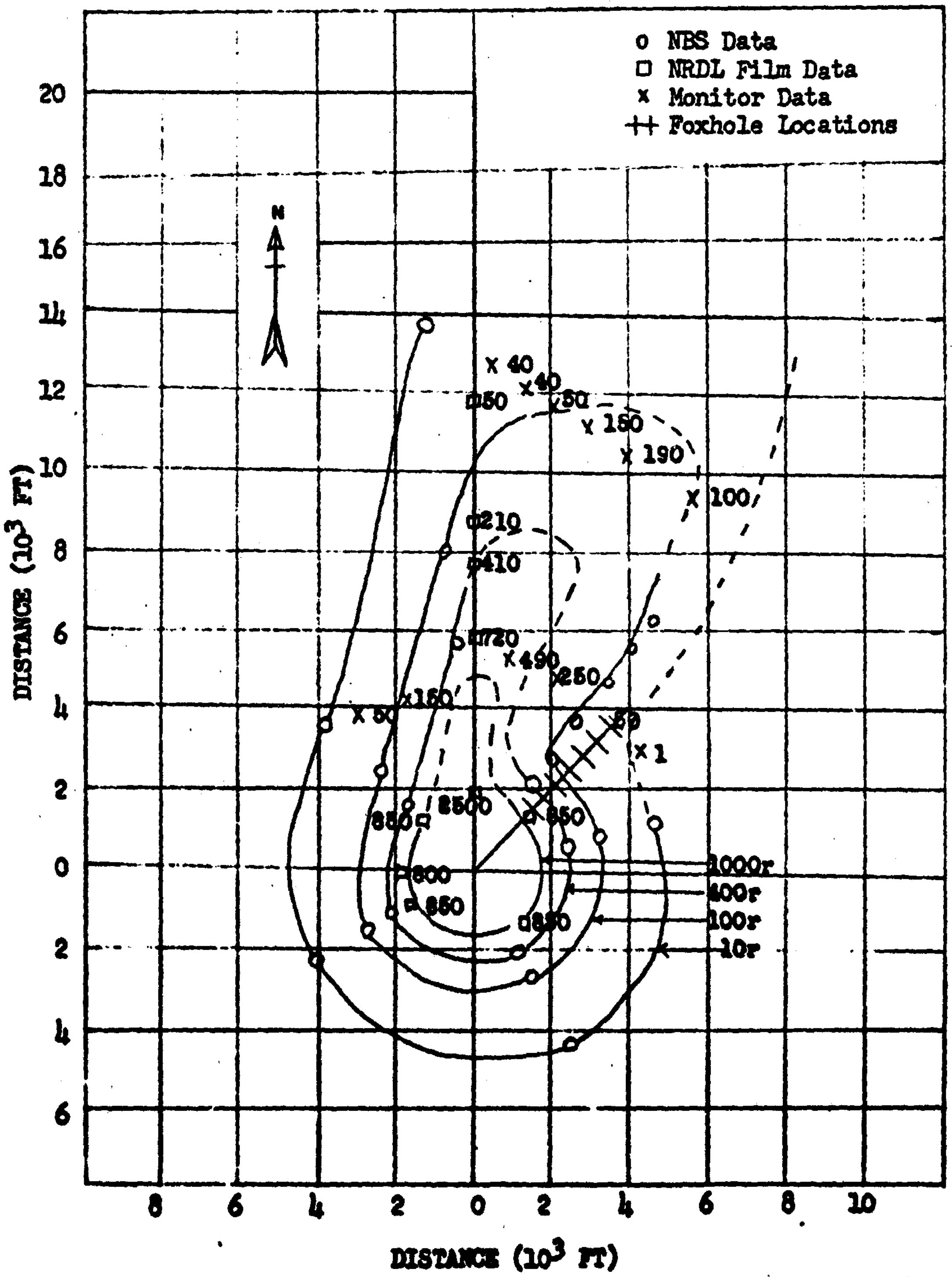

Fig. 3.6 Underground Burst, Iso-Dose Contours at 1 Hour

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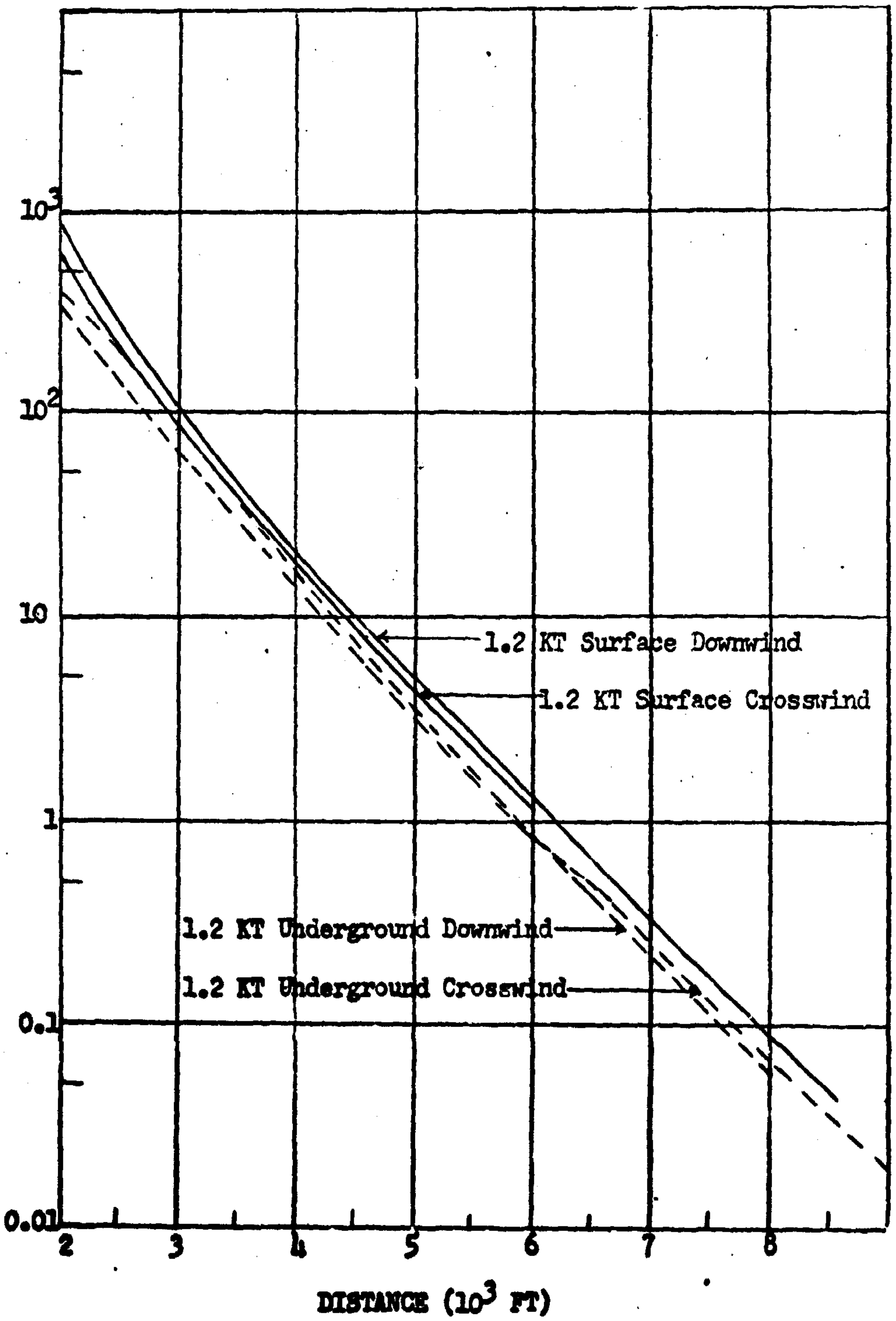

Fig. 3.7 Total Dose at 10 Seconds (Surface and Underground Bursts)

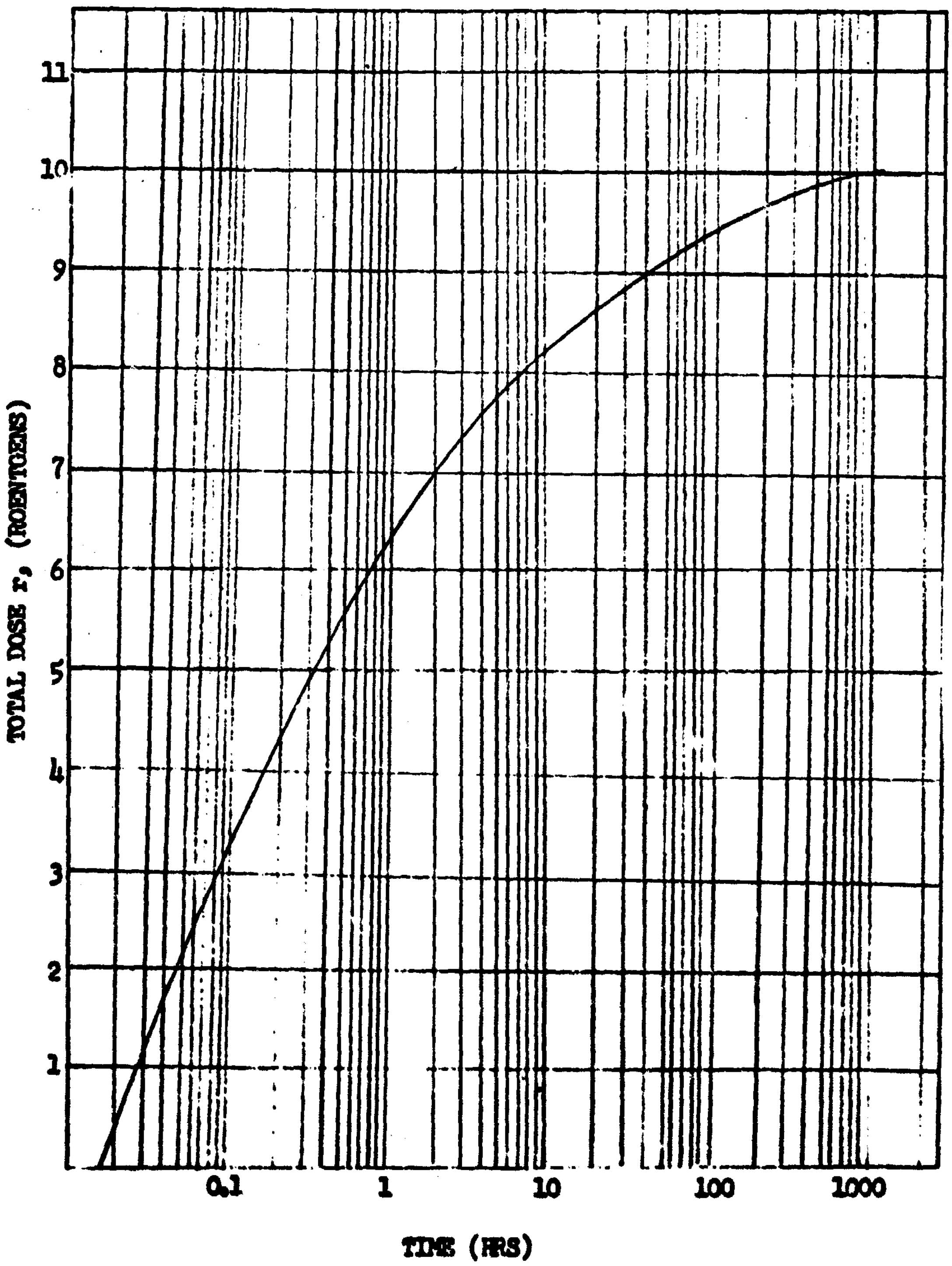

Fig. 3.8 Total Accumulated Dose
(Based on 1 r per hr at 1 hr and $t^{-1.2}$)

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CHAPTER 4

DISCUSSION OF RESULTS

4.1 GAMMA DOSES FROM SURFACE DETONATION

The gamma doses recorded during the surface detonation are given in Table 3.1. The readings are consistent among themselves and can be easily interpreted from the contours and graphs given in Figs. 3.1 through 3.3 and 3.7. Consider the dose of 800r, measured 3 feet above the foxhole located 2000 feet from the detonation. Fig. 3.7 shows that the total dose to be expected at 2000 feet one hour after the burst was between 600 and 800r. Figs. 3.1 and 3.8 show that the contribution of residual activity to the total dose after one hour was small, approximately 15r. However, it must be remembered that the above illustration pertains to crosswind locations only; in the downwind direction surface total doses of about 800r were found as far as 7000 feet from the detonation at H+1 hours, (see Fig. 3.3).

The doses in the foxholes at locations below the surface fell off sharply from the surface values. Analysis of the data shown in Table 3.1 indicates that the doses at the bottom of the foxhole were primarily the result of the scattering of prompt radiation. For example, the average value of the films at the bottom of the foxhole 2000 feet from the surface shot was about 32r and the prompt radiation on the surface was 600r, (see Fig. 3.7). Therefore, about 5 per cent of the prompt surface radiation reached the bottom of the foxhole. The results from Operation BUSTER indicated that this dose was just about what should be expected from initial radiation at the bottom of two-man foxholes. Of course, if the foxhole were located directly downwind, the dose would be higher due to an increased amount of fall-out into the foxhole. However, as will be shown in the analysis of the results from the underground detonation, only the radioactive matter that fell into the foxhole contributed to the total dose, the radiation field on the surface surrounding the foxhole had very little effect on the doses at the bottom.

4.2 GAMMA DOSES FROM AN UNDERGROUND DETONATION

The doses received on the surface and in foxholes at various distances from the point of detonation are given in Table 3.2. With the exception of the 2000 foot station, all badges gave readings

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consistent with the contours shown in Figs. 3.4 through 3.6. The 2000 foot station gave a reading of 3850r, considerably higher than expected from the contours. However, examination of Fig. 3.6 shows that although the total dose contours are accurate over large distances, small areas of very high activity existed in certain locations even though the surrounding areas gave relatively low radiation doses. This was undoubtedly caused by the concentration of a large amount of fall-out in these locations or by a higher specific contamination of the fall-out in that particular region. Consider the dose of 73r obtained 5000 feet from the burst. From Fig. 3.6 the total dose after one hour at the distance should be about 20r. Figs. 3.4 and 3.7 show that the residual radiation after one hour added about 27r, for a total of 57r. But, data from monitor readings as shown in Fig. 3.6 indicated that the total dose after one hour was 50r, instead of 20, in the area where the 5000 foot station was situated. If the 27r residual radiation were added to this, the result would be 77r which is very close to the reading obtained by the film.

Comparison of the results obtained during the underground burst with those during the surface burst showed that the total gamma doses were greater at all distances following the underground detonation. The increase was due primarily to the greater amounts of radioactive matter that fell from the floud. The doses dropped sharply beyond 2000 feet to reading of about 1000r at 2500 feet and 175r at 3000 feet, (see Table 3.2). Consideration of the doses recorded at these stations lead to an estimate of the effectiveness of foxholes as shields against gamma radiation from an underground burst. In the 2500 foot foxhole, a dose of less than 100r was measured at the bottom, while the dose 3 feet above the surface was approximately 1000r. Clearly, personnel on the surface would be exposed to lethal doses while those protected by foxholes would receive relatively unimportant doses.

Analysis of the doses obtained at the lower levels inside the foxholes indicated that only scattered prompt radiation and radioactive matter that fell into the foxholes contributed greatly to the measured doses and that the attendant surface radiation field was relatively unimportant. This conclusion arose from the fact that the films at the bottom of the two-man and one-man foxholes received about the same doses, see Table 3.2, although the one-man foxhole had only one-half the area of opening. Therefore, if the column and cloud contributed greatly to the doses at the bottom, a greater reading should be expected in the two-man foxhole. The same argument is true with respect to the surface contamination surrounding the foxholes. If this contamination contributed greatly to the doses inside the foxholes through radioactive decay, then it should have a greater effect on the badges in the two-man foxhole because of the greater opening.

This was seemingly not the case. Moreover, Reitmann of the Engineer Research and Development Laboratories, stated in his report on Project 6.2, Land Reclamation, that less than 10 per cent of the surface activity was found at the bottom of a 4 foot trench that was dug in a contaminated area after the surface burst of Operation JANGLE.

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CHAPTER 5

CONCLUSIONS

5.1 FOXHOLE SHIELDING OF GAMMA RADIATION

5.1.1 Surface Detonation

Standard foxholes provide excellent protection to personnel from the gamma radiation emitted during the detonation of an atomic weapon on the surface of the ground. The results from the comparatively small sized weapon employed in Operation JANGLE show that 2000 feet from the burst, the location of the closest foxhole doses of about 60r were measured at the bottom of a foxhole, less than 10 per cent of the dose measured 3 feet above the surface of the ground. Due to the location of the foxhole in the crosswind direction, the dose at the bottom was caused primarily by scattered prompt radiation plus a small contribution from the residual activity of the fission products on the surface of the ground. In the downwind direction there would be a contribution from matter that falls out from the cloud into the foxhole in addition to the above mentioned. This fall-out will depend on the wind velocity for a given sized weapon, and although it is expected to increase the dose in the foxholes, especially in those located close to the detonation, it is relatively unimportant in comparison to the prompt and residual activity since it can be easily shoveled out of the foxhole in a short time.

5.1.2 Underground Detonation

With the possible exception of those located in the area close to the point of detonation where extensive fall-out occurs, foxholes also provide effective shielding in the case of an underground detonation. Even within this area of extensive fall-out, which at Operation JANGLE extended approximately 2000 feet, the high doses recorded in the foxholes could be greatly reduced by digging out the radioactive matter that fell into the hole. It is highly probable that one-half the doses recorded in the foxholes located within 2500 feet of the detonation at Operation JANGLE were directly attributable to this type of fall-out and most likely a higher percentage at distances greater than 2500 feet.

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5.2 SOURCES OF RADIATION CONTRIBUTING TO DOSES

The doses obtained from the detonation of atomic weapons on the surface or underground receive contributions from prompt radiation, residual activity due to fall-out of radioactive matter, and possibly radiation emanating from the activity of the solumn and cloud.

5.2.1 Surface Detonation

The complete doses at the bottom of foxholes in this operation were attributable to scattered prompt radiation. No contribution from fall-out or cloud and column activity was evident but it is expected that fall-out would have increased the doses if the foxholes had been located in the downwind direction.

5.2.2 Underground Detonation

The greatest portion to the total dose measured at the bottom of foxholes apparently came from the fall-out matter in the foxhole. The contamination on the surface of the ground surrounding the foxhole contributes only about 10 per cent to the doses at the bottom and the prompt radiation could not contribute more than occurred in the surface burst since both weapons were the same size. Yet, in all cases the doses were considerably higher during the underground detonation leading to the obvious conclusion that matter falling into the foxholes played the most important role, also, the doses in the two and one-man foxholes were equal although the two-man foxhole had twice the opening area. If the column or cloud activity contributed greatly to these doses, it was expected that the doses in the two-man foxhole would be about twice as great as that in the one-man.

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CHAPTER 6

RECOMMENDATIONS

6.1 TESTS

If future tests are planned which include the surface and underground detonation of larger weapons than 1.2KT, it is recommended that another project of this type be undertaken to investigate the validity of existing gamma radiation scaling laws.

6.2 STUDIES

A study should be undertaken to investigate the ratio of the doses at the bottom of foxholes to the dose rates existing on the surface surrounding the opening of the foxhole. It is possible that a constant ratio exists between the two that would facilitate predicting the doses expected in foxholes for all values of surface contamination. It seems that enough data are available for a preliminary study of this type and arrangements are being made for its accomplishment in the near future.

6.3 DISSEMINATION OF RESULTS

The results of this project should be disseminated to troop commanders in the field to form a basis for preliminary training and staff planning since these results together with those of Project 2.6, Operation BUSTER, present a good picture of the protection that foxholes afford against the nuclear radiation emitted by atomic weapons detonated in the air and on or under the ground.

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